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Title of the extended essay: What is the effect of different light combinations on the movement of semiaquatic turtles, red-eared slider (Trachemys scripta elegans) with respect to the position of the light sources.

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conducted her research with animals. She designed her protocol taking into account the IB regulations about ethics, and she worked patiently treating the animals with sensitivity and care. She quickly realised that such behavioral studies are difficult to conduct and that she will need to develop the necessary skills to efficiently conduct research with animal or human subjects in the future.

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Criteria	Achievement level				
	Examiner 1	maximum	Examiner 2	maximum	Examiner 3
A research question	2	2		2	
B introduction	2	2		2	
C investigation	4	4		4	
D knowledge and understanding	3	4		4	
E reasoned argument	4	4		4	
F analysis and evaluation	4	4		4	
G use of subject language	3	4		4	
H conclusion	2	2		2	
I formal presentation	4	4		4	
J abstract	2	2		2	
K holistic judgment	4	4		4	
Total out of 36	34				

EXTENDED ESSAY

IN

BIOLOGY

Research question:

What is the effect of different light combinations on the movement of semiaquatic turtles, red-eared slider (*Trachemys scripta elegans)* with respect to the position of the light sources?

Candidate Name:

Candidate Session Number:

Supervisor:

Examination Session: May 2013

Date of Submission: 30/09/2012

Word Length: 3,907

Supervisor's signature

Abstract

The importance of light pollution in the disorientation, induction of stress and overall decline of the survival rates of aquatic turtles has been thoroughly researched during recent years. However, its importance may still be underestimated in the public discourse.

The present investigation was based on an artificial setting in which the routes of 10 individuals sea turtles, in relation to different combinations of light wavelengths, were recorded, in order to conclude as to whether specific combinations of light act to repel, to attract or do not affect the animals at all. The research question formulated is: What is the effect of different wavelengths of light combinations (white/white, white/yellow, white/green, white/blue, white/red and white/no light) on the distance from the light sources covered by semiaquatic turtles of the species red-eared slider (*Trachemys scripta elegans*) after the same time span (3 mins ±0.1), measured in cm (± 0.05)?

The results suggest that blue light was attracting the animals, whereas red, yellow and no light (dark) were repelling them (paired t test significant differences were found in most of the light combinations, at 95% level of confidence). Green light seemed to have no significant influence over the route selection of the turtles. These observations show that light pollution is greatly affecting the sea turtles and the direction they choose to take, and further research is needed to set the context within which, measures concerning the criteria of seashore exploitation will be eventually developed.

Word Length: 240

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Acknowledgements

I hereby would like to thank for his invaluable feedback and guidance through the Extended Essay writing. Furthermore, I would also like to thank , researcher in the Biomedical Engineering Laboratory Institute of Communications and Computer Systems, National Technical University of Athens, for the provision of journals, and articles without which the bibliographic research and literature review would not have been possible.

List of Abbreviations

ANOVA: Analysis of Variance

CITES: Convention on International Trade in Endangered Species

cm: Centimetre

cos: Cosinus

DC: Direct Current

GO: Governmental Organization

mA: milli-Ampere

MEDASSET: Mediterranean Association to Save the Sea Turtles

NGO: Non-Governmental Organization

pm: Post-meridiem

STDEV (SD): Standard Deviation

tan: Tangent

UNEP: United Nations Environmental Program

V: Volt

W: Watt

WWF: World Wide Fund For Nature

Ethical Considerations

The IB guidelines for animal experimentation policy were seriously considered in designing the experimental procedure. I hereby confirm that the individual animals used involved in the experimental investigation, were not in any way put to harm (deliberately or not), and that they were given time to accommodate in the new conditions before they were tested in each trial. Furthermore, they were put under investigation for only a brief period of time and then they were safely returned to their artificial aquatic environment (aquarium). After the completion of the experimental measurements the turtles were not disturbed in any other way, and presently they currently continue to live under optimal conditions of temperature and food, in their aquarium.

Chapter I: INTRODUCTION

1.1 Background Information

Several species of aquatic turtles, including those that inhabit the sea, as well as those in the lakes, have been dramatically decreased in their numbers during the last decades. The reasons behind their population decline are diverse: pollution of water, loss of habitat, global warming and currently fisheries, all play an important role for the survival of these animals.

Aquatic turtles have been shown to be easily attracted by the glowing lights that are attached on longline fisheries (serving the purpose of attracting fish, like tuna and swordfish) and move towards the light source. Inadvertently, they get hooked and die by drowning, since they are not able to move to the surface to breathe (Wang *et al.* 2007).

Oceanic beaches are narrow strips of sand where people build, live, recreate and carry on daily activities, whereas sea turtles arrive to reproduce in specific times throughout the year. Although the time, turtles spend on sand is very little, their activities are critical for the perpetuation of their species. Humans create huge environmental disturbances in the places they live, which eventually hinder the normal life cycle of the turtles.

One of the most important types of detrimental human effect on the environment of the turtles is light pollution. This type of pollution is different from other types, in that it is energy rather than chemical substances and it does not produce physiological effects on the animals (like oil and heavy elements do); it rather causes psychological stress. It is therefore described as misinformation, rather than a toxic material. Two important aspects of sea turtle behaviour include the nesting site selection and the movement from the beach towards the sea by the hatchlings (Witherington and Martin, 1996).

In conclusion, it is important to understand the effect of light stimuli on the movement of turtles if strategies to avoid both the disorientation of the breeding adults, the movement of the hatchlings towards the sea and their by-catch in fishery lines, are to be implemented.

1.2 Choice of Topic

Greece has many endemic species of plants and animals, most of them under protection from international environmental agreements and governmental (*CITES* and *UNEP*) and non-governmental organizations (NGOs) like *WWF* and *Greenpeace*. In the Aegean Sea, loggerhead sea turtles exist in large populations, especially the species *Caretta caretta*. The Sea Turtle Protection Society of

Greece (*ARCHELON*) started in 1982 an intensive tagging program. Significant numbers of nests were identified along the coastline of Crete and Zakynthos, as well as North Sporades island complex. Nest protection as well as public awareness actions started in 1990. During 2005 the First Aid Station and Environmental Station started its operation in the context of LIFE-Nature project in order to reduce mortality of sea turtles at sea.

Still another organization acting to protect the sea turtles is *MEDASSET* (Mediterranean Association to Save the Sea Turtles) is an international NGO, striving to conserve sea turtles and their natural habitats across the Mediterranean Sea. Apart from conservation it gets involved in scientific research programs, environmental education, lobbying decision-makers and public awareness activities.

Over 7300 km of coastline from North-eastern Aegean to the Island of Sardinia and from the Ionian Sea to Egypt and Libya, were surveyed providing invaluable information on the life cycle of sea turtles.

Trying to be a part of the solution, my driving impulse was to collect data and observe the turtles in response to the light pollution that surrounds them, which among all other forms of pollution, has been given inadequate attention. However, its effects might be much more deleterious than we think, greatly reducing the numbers of the sea turtles through time.

1.3 Literature Review

In a review by Raymond (1984), a first summary of light pollution effects of sea turtle hatchlings was presented, together with some potential mitigation. The article reported a dramatic decrease in sea turtle attempts to nest at a brightly illuminated beach in Florida, USA. Later reports (Mattison *et al.* 1993) showed reductions in nesting attempts in places where lighting piers and roadways came in proximity to beaches. Many other articles (Salmon *et al.* 1995; Dodd, 1988; Martin *et al.* 1989) support the relationship between illuminated beaches and decrease nesting.

Approximately one to seven days after egg hatching, the new born turtles emerge from under the sand and all of them orient towards the sea. This process happens mostly during night time. In natural conditions the hatchlings crawl in frenzy to the sea. Any delay will result to death: exhaustion, predation and dehydration will kill the hatchlings, upon delay (Mann, 1978).

A large amount of evidence supports that brightness is an essential cue for the hatchlings to find the ocean. It has been shown that they move towards bright light sources, both natural and artificial (Mrosovsky and Shettleworth, 1968).

The turtles' response to light colour is different from response to light intensity. Colour discrimination by turtles has been extensively researched. Experimental data by Mrososvky (1972) shows that turtle hatchlings prefer blue light illuminated directions than red light ones. Further conditioning behavioural experiments showed that a red light, being less intense than blue, has to be 100-600 times more intense in order for the hatchlings to equally prefer it (Fehring, 1972; Granda & O'Shea, 1972). However, it seems that it is not the intensity of yellow light that affects the hatchlings, but its colour, because other high intensity colours (near-ultraviolet, violet and green) do not elicit any attraction or aversion from the hatchlings. Further research by Witherington (1992) showed that the addition of high intensity yellow light to any other attractive light source eventually decreases its attractiveness to the hatchlings. Low intensity yellow light weakly attracts hatchlings, whereas high intensity yellow light results in aversion (Witherington and Martin, 1996).

A probable explanation is that the reduction of hatchlings' attraction to yellow light sources, inhibits them from being misdirected from the moon or the sun. However, controversial evidence exists as to the extended influence of the sun/moon to hatchlings' sea finding process; Rhijn (1979) and other scientists report an insignificant influence of the sun to orientation of the hatchlings, whereas, Witherington (1992) and others have shown that some species of turtles and affected indeed.

1.4 Research Question

The research question formulated in this investigation is: *What is the effect of different light combinations (white/white, white/yellow, white/green, white/blue, white/red and white/no light) with respect to the position of the light sources covered by semiaquatic turtles of the species red-eared slider (Trachemys scripta elegans) after the same time span (3 mins ±0.1), measured in cm (± 0.05)?*

1.5 Method

The distance covered by the turtles will be compared to a control, base line measurement, for each turtle at each trial, in which only one light source will be switched on (white light), whereas the second light source will be switched off. Three distance measurements will be recorded for each trial: the first distance is between the initial position of the turtle and its final position after 3 minutes

(±0.1). The second distance is between the final position of the turtle and the first light source, whereas the third distance is between the final position of the turtle and the second light source, after 3 minutes. Therefore, the correlation of the combination of the different light wavelengths to the distance covered by the animals in a given time window will be assessed.

The hypothesis that is tested is the following: The expectation is that all aquatic turtle individuals participating in the experiment (10 individuals) will show similar responses to the different combinations of light, finally arriving at similar distances, after 3 minutes (±0.1), since they all belong to the same species and chronologically have hatched within a certain time in the past. In terms of the different combinations of light the turtles are expected to show variations in their final distance from the two light sources, as suggested by the bibliographic references described earlier. However, the expectation to measure difference in the distance from the 2nd source of light (the variable one, having different color than white) comes from the fact that the animals are differently affected by the different light wavelengths (both their intensity and their color), as is supported by bibliography.

1.5 Variables

1.5.1 Dependent variable

The distance from the light sources covered by semiaquatic turtles of the species red-eared slider (*Trachemys scripta elegans*) after the same time duration (3 mins ±0.1), measured in cm (± 0.05).

1.5.2 Independent variable

The different light combinations used as the first and second light sources for each individual turtle. These combinations are: white/white, white/yellow, white/green, white/blue, white/red and a control in which the first light source will be white and the second light source will be switched off.

1.5.3 Controlled variables

Firstly, the species of the aquatic turtle participating in the investigation is the same: *Trachemys scripta elegans.* This is important because different species may show different responses to the same wavelength of light, therefore the results will not be comparable.

Secondly, the number of individual turtles that are investigated will be the same: 10 individuals, which are going to be exposed to all different wavelengths of light combinations.

Thirdly, the tests for each individual turtle will be the same, 15 trials for each different wavelength light combinations investigated. The importance of the collection of a large number of measurements lies on the fact that statistical analysis can be performed (t-test) to statistically assess the significance of the results.

Fourthly, the environment in which each individual turtle is kept, prior to investigation, is the same (temperature, food, size of aquarium and salinity / pH of water). These parameters could affect the well-being and health of the animals, their behavioral patterns, as well as their motility.

A fifth parameter that must be controlled is the duration of time that each individual turtle is allowed to move under the influence of the two light sources. This duration of time will be 3 minutes (±0.1) for each trial, preceded by an accommodation time interval of 5 minutes (±0.1) for each set of trials for the same individual turtle, during which ambient light (first and second light sources are both switched off) will be the only source of lights for the turtle.

Furthermore, the set-up in which the investigation will be carried out will be the same in each trial; a rectangular corridor of 150.00cm length (±0.05cm) and 60.00cm width (±0.05cm), constructed using wooden beams of 5.00cm height (±0.05cm).

The substrate on which the set-up will be constructed will be the same, small pebbled earth, with rough surface texture, for the simulated environment to be as close to the natural setting of the turtles as possible (newborn individuals crawl on sandy/rocky beaches to reach the sea).

Still, another important controlled variable is the age of the individual turtles participating in the experiment. All ten individual turtles are born at approximately the same time, so their age at the time of the experimental measurements will be approximately the same. This parameter is significant since each turtle must be young enough so that the simulation of its crawling towards the sea to be as genuine as possible.

In addition, the gender of the turtles participating in the experiment will be the same to avoid any discrepancy or deviation, caused by a different behavioral pattern of response due to different gender; therefore all the individual turtles will be females.

Moreover, the two light sources used in the experiment will have the same distance from the initial position of the turtle in the set up. The distance chosen is 75.00cm (±0.05) from the initial placement of the turtle whereas the two lamps are exactly opposite to each other and at the center of the side of the

rectangular set-up (a clear depiction of the set-up is shown in photographs, *Appendix 1*).

Furthermore, the height of the two light sources from the substrate surface where the turtle individual will crawl is the same, 20.00cm (±0.05). The parameters concerning the light source distance from the initial position of the turtle are important so that the different light combinations to have the same influence on each individual turtle.

Additionally, the type of light bulb used in the two light sources will be the same; a led lamp, not producing heat, of 3 Watts. Thus, the intensity of the light will be kept constant in all trials.

Another important parameter that must be maintained constant is the type of color membrane used to cover the light source in order to produce the desired color (wavelength). Although the membranes used are of different color the texture and thickness will be the same, so that no interference with the constancy of the light intensity will be introduced in the measurements.

Finally, the time of the day during which the measurements will be performed is the same (7.30 pm), in order for each turtle to accommodate under the same ambient light and temperature.

Chapter II: PROCEDURE

2.1 Materials & Apparatus

The exact equipment and materials used are shown in the following table.

Apparatus	***Uncertainty***
Aquarium (50x20x20cm)	
Tap water	
Dried turtle food: Gammarus-mix, raffy I, Sera® Reptil, made in Germany D52518 Heinsberg	
Electronic balance	±0.1 g
Digital Chronometer	±0.1 min
Thermometer	±0.5 °C
Two non-changeable light diodes - LED (TYP V1017/ JANSJÖ, 4V DC, 3W, 750 mA)	
Straw cylinders of the same size and shape, to construct the corridor in which the turtle movement will be monitored	
Measuring tape meter	±0.05 cm
Small pebbled earth surface substrate Camera (Sony Cyber-Shot DSC-TX55, 16.2 MegaPixels)	
Coloured membranes: red, blue, green, yellow, transparent	
Rubber bands	
Gloves disposable (latex)	

2.2 Living Organisms

- *Trachemys scripta elegans* female individuals (10)

2.3 Experimental method

1. A glass aquarium (50x20x20cm) was used to accommodate the 10 female individuals of *Trachemys scripta elegans* turtles.
2. The aquarium was filled with tap water and placed in a well aerated, sunlit area, with ambient temperature, ranging from 24°C to 30°C (±0.5).
3. Ten female turtles of the species *Trachemys scripta*, subspecies *elegans* were purchased from Zoo Planet Pet shop[1], all of which were born approximately the same hatching time.
4. Special food in the form of dried gammarus and shrimps was given to the animals on a daily basis (3 shrimp/gammarus individuals per turtle per day).

[1] "Zoo Planet." *Zoo Planet.* N.p., n.d. Web. 21 June 2012. <http://www.zoo-planet.gr/>.

5. The setting of the experimental measurements was constructed in the following way (*Figure I*):

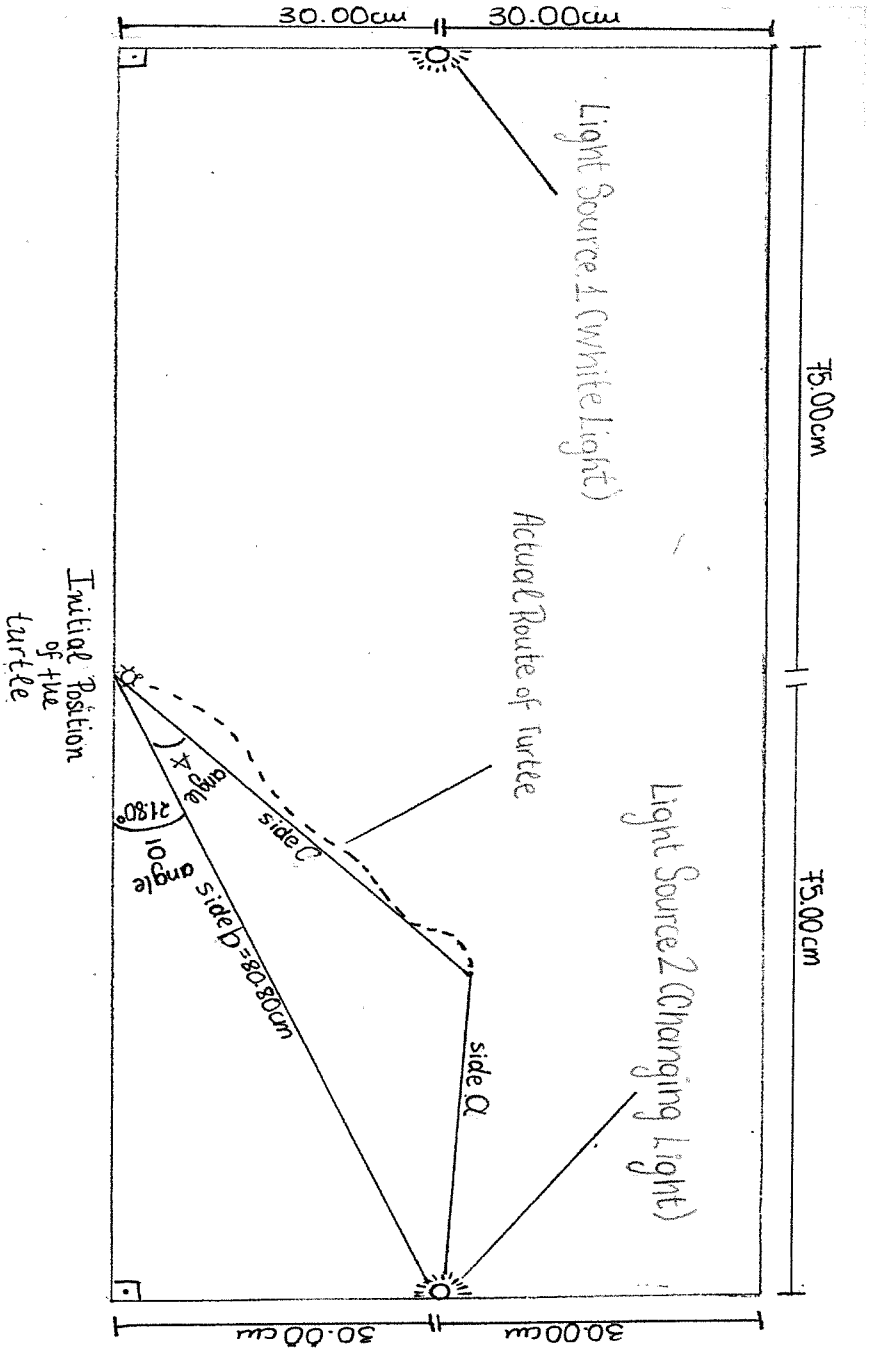

Figure I: geometric representation of the experimental setup, to show the stepwise calculation used to confirm the movement of the turtles towards or away from the 2nd light source (changing light)

a. Four straw cylinders of different length (two of them 150.00cm and two of them 60.00cm) and same height 5.00cm each were placed at right angles to form a rectangular corridor in which the movement of the turtles would be recorded.

b. The two light diodes were placed at the two-shorted sides of the rectangle, exactly in midpoint (at 30.00cm).
c. The placement of the two diodes was such as to be exactly opposite to each other.
d. The height of the diodes and the angle of the incident light were measured to be exactly 20.00cm and 45°.
e. In the middle of the longest wooden beam (at 75.00cm of the 150.00cm beam), a marking spot was drawn. At this exact spot, each turtle individual was initially placed, at the beginning of each measurement trial.
f. The exact setting, prior to measurement recordings is depicted in (photographs in *Appendix I*).

6. Preliminary testing of the setting was performed by allowing the turtles to move into the corridor without any special light present (only ambient light was reaching the animals).
7. The measurement protocol followed was:
    a. The first individual turtle was placed inside the rectangle at exactly the marking spot.
    b. The timer was set and the turtle was allowed to move around for 5.0 minutes (±0.1).
    c. During this accommodation period, the two light diodes were switched off; thus, the only light source for the animals is the ambient light.
    d. The procedure was taking place at the same starting time (7.30 pm).
    e. After the accommodation period was completed, the control measurement took place; the first light source was switched on (white light) whereas the second light source was switched off, thus simulating the natural night environment of the animal (naturally the only light source at night for turtles in the wild is the moon light).
    f. The timer was set and the turtle was allowed to move around for 3.0 minutes (±0.1).
    g. At the end of the time period, the final place of the turtle was marked and the distance from the switched on light source, the distance from the initial position of the animal and the distance from the switched off light source, were all recorded.
    h. Then, for the same turtle individual, the first light combination measurements were carried out, in which both light sources were switched on, in the following series of wavelength combinations: white/white, white/yellow, white/green, white/blue, white/red.
    i. Each combination of wavelengths was replicated for each animal 15 times in total.

j. Procedure steps (**a**) to (**i**) were repeated in exactly the same way for all ten turtle individuals in subsequent days at the same starting time.

8. After all measurements were collected their analysis was carried out.

2.4 Statistical Analysis of the Measurements

The statistical approach chosen was the descriptive statistical analysis and then paired-samples t test in order to identify the significance between the differences observed in the movement of the turtles and the changing lights. The IBM SPSS Statistics program was employed and the tabulated results are analyzed.

Chapter III: RESULTS

3.1 Raw Data

The following tables contain the raw measurements collected during the experiment.

Table 1: *Distance from the two light sources and the initial position of Turtle I at each different light combination*

Replicates	Distances covered by Turtle I /cm ±0.05																	
	Light combinations /1st light source-2nd light source																	
	White/no light			White/white			White/red			White/yellow			White/green			White/blue		
	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position
1	22.00	119.00	55.00	65.00	84.00	30.00	68.00	85.20	18.15	32.30	101.20	38.20	77.35	72.10	22.15	112.15	32.20	57.10
2	38.00	109.10	43.00	70.00	80.50	20.05	72.15	78.35	25.20	27.85	125.10	55.20	76.40	71.85	22.10	121.00	57.25	28.10
3	62.80	93.00	19.00	74.50	78.20	23.10	76.25	79.55	28.30	48.00	112.20	32.40	76.50	77.30	19.15	125.50	51.45	30.20
4	69.00	89.50	12.00	69.00	84.20	26.80	78.80	73.10	21.25	39.10	118.30	38.75	78.20	74.15	23.40	115.25	62.60	42.45
5	64.20	84.00	33.70	78.20	80.90	18.50	64.55	82.20	25.65	24.50	126.20	56.85	69.85	82.20	26.75	142.20	23.10	58.60
6	61.60	88.90	40.00	82.10	76.55	21.65	69.00	79.65	31.35	21.10	132.60	55.75	74.60	78.55	11.25	135.30	22.40	68.60
7	52.40	88.20	12.00	81.95	78.70	28.55	80.25	69.10	35.70	24.70	125.50	52.25	72.35	77.95	34.20	142.05	10.15	72.40
8	56.00	92.50	34.00	76.65	78.30	15.15	78.10	70.35	29.60	28.25	120.75	49.50	76.25	75.30	32.20	136.10	17.65	71.70
9	44.70	101.00	39.00	74.50	79.10	16.70	72.35	78.70	24.55	30.05	122.20	45.60	74.55	75.65	22.30	138.85	14.40	69.90
10	36.50	112.80	40.00	79.90	81.25	19.40	70.85	79.90	19.05	32.70	114.65	38.45	78.45	75.25	33.35	142.70	10.10	78.85
11	29.80	119.00	46.00	71.25	87.10	8.50	69.00	82.05	21.40	29.20	117.25	36.60	78.75	74.05	24.70	140.40	9.05	82.80
12	32.10	116.20	39.30	72.35	88.60	11.75	71.65	80.20	18.35	25.55	111.75	32.20	82.25	67.15	17.55	142.30	10.25	81.65
13	30.90	110.10	36.70	75.70	78.90	23.40	78.05	74.30	26.25	28.10	116.90	36.65	71.35	79.05	11.25	145.55	7.05	85.50
14	34.50	114.90	42.80	69.40	82.50	38.45	82.15	60.05	28.20	29.90	107.95	31.00	74.15	77.10	16.10	137.45	9.90	79.95
15	30.05	111.70	36.15	72.40	79.30	44.60	83.20	59.25	30.35	28.05	115.30	34.70	69.65	80.10	18.15	145.75	5.90	86.50

Table 2: *Distance from the two light sources and the initial position of Turtle II at each different light combination*

Replicates	Distances covered by Turtle II /cm ±0.05																	
	Light combinations /1st light source-2nd light source																	
	White/no light			White/white			White/red			White/yellow			White/green			White/blue		
	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position
1	36.20	105.20	42.15	72.05	76.25	19.20	78.05	72.10	18.10	16.50	95.95	25.20	82.10	70.70	12.10	100.20	65.25	21.10
2	42.80	99.30	34.20	83.15	70.00	25.30	76.00	70.25	22.20	19.35	108.10	28.35	78.75	69.20	22.75	110.15	45.10	36.20
3	45.70	97.70	28.15	88.05	69.20	32.20	74.10	77.20	19.15	27.20	108.00	28.15	76.10	73.25	27.20	132.05	28.75	52.30
4	65.20	85.30	35.35	71.35	78.10	11.05	81.10	68.15	18.30	30.10	103.50	23.30	80.25	68.10	35.10	105.10	50.20	35.00
5	66.20	82.80	68.70	68.20	81.40	18.15	71.20	78.70	17.20	32.25	112.75	32.45	85.00	64.75	19.15	99.20	52.45	68.10
6	75.30	79.20	52.10	75.40	79.75	21.40	65.05	82.95	17.75	28.05	117.60	38.50	69.25	75.20	28.15	98.15	56.05	58.55
7	35.10	98.10	19.75	79.50	70.00	28.55	68.10	79.20	19.45	29.10	111.10	32.05	65.20	72.35	30.00	135.70	10.15	79.10
8	29.20	102.30	22.75	70.05	78.70	30.00	71.25	76.35	18.00	12.20	122.35	42.75	60.15	85.20	18.05	142.85	32.70	53.15
9	71.90	82.40	40.15	82.95	72.25	19.10	65.25	85.10	20.05	28.35	102.75	22.00	75.10	88.05	19.20	112.35	45.00	48.20
10	38.10	108.95	38.30	80.90	69.10	21.40	67.10	82.00	17.65	39.10	98.05	19.70	78.35	71.00	25.30	129.00	21.75	72.10
11	42.30	106.75	52.55	76.75	75.90	28.05	59.20	90.25	12.05	40.20	10 0.00	22.80	81.05	70.40	18.00	114.40	45.05	66.05
12	69.20	80.10	41.45	82.25	72.35	22.80	65.60	87.10	8.10	42.55	106.30	31.05	76.00	72.85	28.15	121.20	28.90	62.00
13	58.70	88.95	46.70	90.00	65.05	17.10	72.15	80.15	14.20	35.60	108.70	32.90	70.05	81.20	22.05	125.10	40.00	50.35
14	64.30	84.25	51.85	75.05	72.00	10.10	75.00	78.90	28.25	51.20	99.20	42.00	75.65	80.10	23.80	131.90	23.70	57.25
15	68.10	81.50	62.05	79.40	71.25	12.90	78.15	71.35	32.45	43.00	102.15	46.40	81.20	75.20	9.15	140.10	18.75	63.05

Table 3: *Distance from the two light sources and the initial position of Turtle III at each different light combination*

Replicates	Distances covered by Turtle III /cm ±0.05																	
	Light combinations /1st light source-2nd light source																	
	White/no light			White/white			White/red			White/yellow			White/green			White/blue		
	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position
1	28.25	112.05	60.10	68.20	82.50	37.55	29.10	110.20	41.05	11.25	124.50	49.55	85.30	67.85	22.05	118.15	40.25	48.30
2	34.50	102.65	64.70	78.05	84.20	35.05	31.35	109.05	38.05	14.35	134.30	54.50	80.20	69.05	15.20	112.45	30.55	50.45
3	36.20	104.70	68.85	72.30	79.30	22.20	46.35	104.00	27.05	25.40	102.35	39.80	78.40	75.05	22.80	118.25	38.50	55.40
4	57.10	121.10	59.05	65.55	88.30	21.90	42.40	102.45	21.75	18.40	114.60	38.50	65.10	88.05	24.45	121.35	28.50	55.40
5	59.20	117.35	61.20	77.10	79.20	21.35	37.10	97.35	22.10	22.25	127.20	59.10	75.50	78.00	32.15	112.35	37.60	45.75
6	42.50	122.65	70.70	88.10	72.15	20.30	29.20	111.05	35.50	28.20	110.15	32.30	76.10	79.50	12.15	125.55	23.20	60.50
7	55.60	97.05	17.35	79.15	76.35	22.10	27.20	112.80	34.65	26.30	112.10	35.15	74.40	78.10	25.55	130.15	20.05	64.00
8	49.20	95.50	22.10	84.20	72.30	24.95	38.65	109.05	36.40	30.15	103.60	29.20	79.20	74.50	18.15	128.25	28.55	52.50
9	48.70	72.25	18.10	88.15	68.30	22.10	34.75	108.65	30.15	9.30	97.20	20.65	69.80	79.00	12.10	121.45	35.80	48.35
10	57.55	88.95	17.20	84.20	66.20	21.10	36.85	110.45	32.40	15.35	122.05	48.55	78.15	71.20	23.20	135.35	19.35	62.00
11	39.25	99.05	22.80	79.15	71.30	32.10	42.45	102.70	28.55	44.40	104.25	27.00	76.25	77.10	25.15	112.45	38.45	50.50
12	45.50	102.25	28.70	76.20	77.55	27.20	41.25	98.45	19.40	43.55	102.10	32.30	72.15	78.45	30.10	125.45	30.50	52.50
13	37.60	113.05	34.10	80.10	72.35	23.10	45.55	97.30	21.50	39.20	112.15	37.10	69.40	80.15	12.45	121.80	35.40	49.00
14	37.20	93.00	14.05	76.50	78.20	30.75	49.25	105.40	25.40	37.70	108.25	32.20	65.40	83.45	19.80	128.90	39.35	50.40
15	35.05	98.95	28.25	81.35	76.50	27.35	51.35	106.40	31.50	32.30	111.20	32.10	59.30	86.45	29.50	122.30	42.45	44.30

Table 4: *Distance from the two light sources and the initial position of Turtle IV at each different light combination*

Replicates	Distances covered by Turtle IV /cm ±0.05																	
	Light combinations /1st light source-2nd light source																	
	White/no light			White/white			White/red			White/yellow			White/green			White/blue		
	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position
1	62.20	85.50	12.15	70.75	80.00	12.10	80.80	69.20	21.00	12.30	128.90	55.00	76.20	74.10	19.40	121.10	32.00	51.40
2	40.15	102.20	30.50	78.95	77.20	30.05	78.30	68.35	35.05	20.45	132.25	57.40	71.35	80.80	29.95	131.50	30.40	53.50
3	47.30	96.10	21.05	79.20	70.10	27.05	78.05	76.60	12.35	19.20	135.55	62.10	70.00	83.50	22.40	109.45	40.00	50.10
4	52.35	90.15	40.05	66.60	84.05	5.55	84.05	63.30	20.70	22.50	125.15	45.00	85.55	70.20	15.50	95.30	62.80	31.40
5	68.50	80.90	57.05	72.05	74.55	32.05	74.05	75.85	27.75	17.75	122.05	48.05	72.00	72.00	22.40	103.70	54.15	42.00
6	78.05	75.05	60.15	60.30	89.20	10.15	69.10	79.35	40.55	27.05	123.55	45.70	63.55	82.00	18.30	109.35	35.45	47.05
7	39.00	101.55	37.15	69.20	76.05	23.40	72.40	79.20	27.75	10.10	130.15	52.10	72.00	76.05	37.50	123.10	28.90	55.30
8	41.30	100.20	27.05	77.70	60.20	32.00	63.35	89.10	31.00	16.70	129.80	55.50	69.45	77.60	18.05	134.00	17.20	65.65
9	48.10	91.15	31.10	55.05	86.00	22.05	71.05	79.00	27.20	18.10	130.70	52.20	79.50	70.25	31.90	111.60	20.40	65.50
10	52.30	90.20	18.35	68.50	84.20	32.15	61.40	89.90	20.25	27.70	121.90	42.40	74.65	76.20	28.10	137.50	32.00	50.50
11	35.40	110.05	32.00	70.25	81.30	19.00	69.20	80.05	32.30	23.25	127.20	55.55	76.45	72.20	28.30	120.10	29.00	60.35
12	57.20	99.05	39.90	75.40	78.20	12.05	68.35	81.05	7.70	28.35	120.70	51.45	72.10	77.90	15.50	136.60	25.00	60.00
13	60.45	92.00	20.05	67.75	86.05	30.50	68.90	85.30	27.75	30.20	118.55	40.50	81.10	68.30	18.65	106.70	51.60	43.30
14	57.70	89.90	25.25	67.20	88.50	11.75	65.25	88.20	40.35	27.30	121.75	42.75	82.00	64.40	21.40	124.30	24.00	58.40
15	62.20	92.10	12.10	74.35	64.30	19.10	72.2	78.05	17.70	19.35	115.80	38.95	78.55	71.60	17.00	110.60	37.90	54.10

Table 5: *Distance from the two light sources and the initial position of Turtle V at each different light combination*

Replicates	Distances covered by Turtle V /cm ±0.05																	
	Light combinations /1st light source-2nd light source																	
	White/no light			White/white			White/red			White/yellow			White/green			White/blue		
	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position
1	21.40	114.50	41.45	76.00	74.20	23.50	70.25	77.00	12.50	15.70	113.40	41.10	76.20	74.10	23.10	114.60	32.50	49.90
2	36.50	101.45	31.35	78.45	75.80	41.00	77.30	75.35	28.00	24.50	102.00	39.00	71.35	80.80	13.00	123.10	22.20	60.00
3	25.80	115.50	35.50	83.25	70.70	32.60	79.40	72.80	34.60	29.90	118.40	41.05	70.00	83.50	19.60	117.05	24.30	58.00
4	63.50	89.10	41.60	69.05	83.00	21.15	73.00	79.60	23.45	34.00	115.10	41.40	80.50	66.40	23.50	99.10	55.40	32.65
5	60.30	89.00	49.30	71.40	78.60	25.65	69.70	82.20	33.50	29.55	112.00	33.60	79.20	72.40	14.65	118.90	32.05	49.10
6	67.60	81.30	31.20	68.00	82.90	32.75	73.20	78.10	12.00	32.25	107.90	35.65	72.80	78.40	23.25	104.60	41.00	44.35
7	56.90	89.20	43.50	67.80	78.90	16.90	72.70	75.90	31.40	37.40	105.10	34.35	79.10	74.35	19.90	109.00	37.20	49.60
8	25.30	125.50	54.00	66.45	81.90	24.05	68.60	80.00	24.50	8.45	130.50	51.30	74.50	75.30	21.40	128.90	23.00	59.00
9	64.20	88.10	31.35	79.80	74.80	34.55	69.40	80.90	32.65	19.50	116.00	39.20	75.90	74.45	14.00	126.10	25.10	57.90
10	41.00	104.00	33.10	78.00	72.40	31.10	76.15	74.50	17.40	31.50	104.00	31.90	70.40	79.00	31.50	126.10	23.90	58.75
11	46.20	102.55	45.70	79.30	72.40	25.70	65.45	88.55	26.60	37.60	112.10	34.20	68.80	81.10	34.70	125.50	28.30	56.15
12	71.00	78.80	32.55	78.45	73.80	9.95	63.80	81.40	28.60	36.70	114.40	35.65	69.15	79.00	31.00	122.50	24.95	58.55
13	64.90	90.15	35.90	85.40	67.45	23.50	68.50	83.05	31.70	31.60	111.50	34.30	79.45	72.50	10.90	113.80	27.20	55.10
14	73.00	78.05	39.90	78.15	76.65	14.30	79.10	73.45	33.40	44.50	101.70	33.10	79.30	69.90	29.00	129.30	23.05	57.90
15	62.30	89.75	42.45	82.10	67.00	28.10	70.60	78.95	45.90	39.60	114.60	41.30	81.75	68.10	25.50	125.10	20.00	62.45

Table 6: *Distance from the two light sources and the initial position of Turtle VI at each different light combination*

Replicates	Distances covered by Turtle VI /cm ±0.05																	
	Light combinations /1st light source-2nd light source																	
	White/no light			White/white			White/red			White/yellow			White/green			White/blue		
	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position
1	11.60	131.10	50.50	80.10	71.40	12.55	77.00	72.40	19.90	10.90	125.80	48.60	65.05	79.00	12.35	100.05	45.40	37.25
2	24.20	123.00	42.40	82.45	68.00	35.75	68.40	81.05	25.20	16.70	124.60	52.20	66.55	80.75	32.45	117.80	27.45	55.45
3	29.10	120.30	48.90	88.05	65.85	22.90	69.60	79.90	29.00	23.50	126.20	45.75	71.80	78.05	18.30	114.55	30.35	52.60
4	51.90	93.00	19.20	62.10	89.20	9.00	81.50	70.85	12.55	18.30	125.00	46.00	65.50	81.35	31.30	109.50	131.40	51.35
5	57.80	79.00	31.60	75.90	72.80	19.80	82.30	65.10	18.70	33.70	107.40	42.80	59.00	90.55	27.80	125.50	20.60	64.40
6	51.70	99.10	33.80	62.40	78.50	24.00	78.60	71.00	24.60	26.05	113.00	38.00	74.70	72.35	25.20	122.55	20.65	61.35
7	43.50	88.00	14.60	70.90	74.00	23.10	65.10	77.85	22.30	20.25	128.45	50.05	73.30	77.80	15.35	130.45	15.90	65.35
8	31.80	118.00	42.30	69.00	76.05	35.40	73.70	74.90	31.90	19.95	121.40	48.10	76.50	72.20	12.30	122.50	24.45	56.45
9	54.60	92.00	25.50	68.30	76.70	13.75	75.20	83.55	11.90	23.80	119.30	42.90	74.35	76.40	12.20	121.75	25.50	55.55
10	30.20	113.95	34.00	68.10	79.20	25.00	70.75	79.10	18.60	9.70	130.30	52.50	80.45	69.00	31.20	107.60	32.70	53.65
11	31.10	113.05	40.30	81.80	70.10	22.90	69.80	80.00	34.20	10.50	127.00	49.70	73.35	80.45	27.25	110.75	24.45	58.20
12	67.35	84.90	21.05	70.35	78.60	15.00	68.81	79.00	14.90	23.00	115.10	39.40	76.30	75.40	10.15	100.40	42.75	38.80
13	61.30	88.22	12.95	81.90	65.60	19.70	64.90	86.60	19.90	39.30	100.00	25.35	72.80	78.45	13.35	116.35	30.65	51.50
14	67.20	82.20	24.55	65.05	81.05	27.40	74.00	75.60	10.80	34.65	112.90	41.00	68.85	81.55	35.50	99.90	45.40	45.50
15	54.10	91.00	28.50	90.50	56.30	34.70	77.30	74.00	16.50	12.05	126.80	48.30	69.65	73.45	14.40	95.65	45.75	41.50

Table 7: *Distance from the two light sources and the initial position of Turtle VII at each different light combination*

Replicates	Distances covered by Turtle VII /cm ±0.05																	
	Light combinations /1st light source-2nd light source																	
	White/no light			White/white			White/red			White/yellow			White/green			White/blue		
	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position
1	14.40	124.50	49.25	75.50	71.35	11.25	80.80	68.75	34.40	19.90	120.35	43.30	59.90	84.40	30.05	114.00	31.85	51.50
2	11.20	130.45	55.55	70.45	77.35	15.50	69.85	79.95	40.50	23.40	120.45	42.45	66.75	80.80	43.40	123.75	24.95	58.00
3	20.25	128.80	52.50	71.25	78.50	16.75	71.45	76.60	38.85	12.35	130.35	49.90	68.95	79.90	40.55	119.80	28.00	55.00
4	23.40	120.40	53.65	81.45	70.50	23.25	77.50	72.35	50.55	28.90	118.90	45.95	71.30	75.50	19.95	106.75	34.95	47.75
5	27.80	118.55	42.45	80.40	68.75	34.50	72.45	77.45	57.40	27.85	120.45	42.75	72.45	77.45	18.85	109.95	34.75	46.55
6	23.45	120.60	45.65	77.80	74.40	31.55	77.55	73.30	38.50	14.45	120.55	40.90	77.35	75.60	23.45	111.80	41.05	42.35
7	19.95	128.50	49.90	74.55	77.80	25.45	72.45	78.50	25.60	16.75	117.90	39.55	70.00	78.55	28.90	109.35	37.90	48.60
8	23.20	120.45	47.85	71.35	79.95	27.35	79.85	72.80	41.30	19.95	115.55	37.75	65.45	80.55	31.55	118.90	24.75	59.65
9	27.80	118.50	41.35	74.80	76.50	39.65	71.35	77.60	55.75	14.50	132.35	54.50	55.90	85.40	28.80	112.45	35.95	47.85
10	18.45	120.45	44.35	79.85	68.95	31.25	79.95	70.25	48.85	16.65	138.80	59.60	59.95	83.20	34.85	110.70	30.80	51.90
11	21.00	114.50	50.00	72.25	76.25	19.80	74.25	76.50	56.35	18.95	124.65	46.30	61.30	80.05	51.35	118.30	31.65	51.05
12	28.50	106.65	34.45	81.35	68.80	16.50	79.90	68.80	42.80	13.45	131.75	53.55	77.05	73.45	38.00	130.05	15.65	68.85
13	26.50	111.45	37.75	82.45	66.50	24.45	78.20	69.95	39.95	18.00	123.90	52.50	72.30	76.60	49.95	128.80	20.55	63.40
14	22.60	112.45	34.80	77.80	71.25	28.85	69.55	81.45	29.00	23.40	117.50	39.90	68.85	77.80	52.25	117.75	27.75	60.90
15	18.85	119.60	39.90	69.90	78.85	30.25	72.35	77.80	27.80	27.80	115.00	39.95	67.50	81.25	53.20	126.00	24.00	57.95

Table 8: *Distance from the two light sources and the initial position of Turtle VIII at each different light combination*

Replicates	Distances covered by Turtle VIII /cm ±0.05																	
	Light combinations /1st light source-2nd light source																	
	White/no light			White/white			White/red			White/yellow			White/green			White/blue		
	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position
1	22.35	120.55	40.15	73.40	76.55	13.45	78.65	70.95	14.50	12.35	121.25	41.00	70.55	78.75	24.00	100.05	44.70	49.95
2	27.75	101.80	31.35	69.95	78.80	14.40	79.00	70.00	12.10	18.80	120.50	49.80	75.45	71.45	43.55	110.85	37.85	54.60
3	22.00	114.45	35.45	68.90	80.85	17.85	75.50	71.45	9.70	11.00	113.00	37.35	68.05	79.00	41.05	123.05	20.65	65.55
4	19.95	116.80	37.40	71.35	75.65	19.90	74.35	73.40	16.75	30.00	109.05	44.50	69.35	80.35	48.85	120.05	26.05	63.25
5	18.80	130.40	49.90	75.65	74.45	23.35	77.25	72.35	30.05	40.25	107.40	29.05	70.75	76.85	42.30	122.25	19.35	75.55
6	29.00	120.45	46.85	70.35	77.85	28.85	78.55	70.45	25.40	38.85	110.05	38.85	63.75	77.80	28.90	99.05	40.75	63.65
7	31.50	110.25	31.45	78.90	73.35	29.00	68.50	78.65	23.35	31.25	106.55	28.80	70.90	76.55	24.50	95.85	47.85	48.75
8	19.75	112.45	39.95	71.35	76.65	27.75	69.60	74.25	28.90	27.85	107.85	45.00	59.05	80.25	19.05	104.50	40.05	49.00
9	28.85	119.90	43.45	69.00	80.00	25.60	71.45	77.45	27.85	23.45	118.00	48.05	64.25	78.65	31.45	103.05	44.85	44.05
10	34.50	110.35	30.35	74.45	75.45	31.20	78.90	73.35	22.80	39.05	105.65	28.85	69.05	73.45	37.75	114.75	32.35	52.25
11	35.90	112.55	37.85	80.55	68.85	35.45	77.20	71.25	18.85	42.50	101.45	31.90	76.50	71.35	29.00	128.65	30.30	53.00
12	31.95	109.80	41.35	78.50	69.00	38.55	68.50	80.55	19.00	18.65	125.05	47.55	72.25	77.00	38.65	130.45	17.85	75.90
13	39.90	106.55	46.65	71.25	75.45	38.00	69.05	78.45	22.75	17.80	121.50	41.00	68.35	81.45	20.50	127.85	14.05	68.15
14	18.85	120.55	42.00	74.50	73.25	41.35	81.00	68.05	26.65	28.90	115.60	44.55	64.80	82.35	19.85	118.75	28.90	54.05
15	14.50	134.80	58.85	76.00	72.35	28.85	79.45	69.85	22.55	26.65	118.95	43.05	66.45	81.00	13.05	100.60	45.65	47.00

Table 9: *Distance from the two light sources and the initial position of Turtle IX at each different light combination*

Replicates	Distances covered by Turtle IX /cm ±0.05																	
	Light combinations /1st light source-2nd light source																	
	White/no light			White/white			White/red			White/yellow			White/green			White/blue		
	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position
1	12.35	136.05	69.00	78.90	71.00	18.90	80.65	68.75	30.55	21.55	123.55	52.55	72.35	77.90	9.55	103.45	36.65	60.45
2	20.45	124.45	44.55	76.55	72.35	50.00	76.05	71.45	14.00	29.00	120.50	43.85	77.85	72.35	19.00	121.00	28.65	53.45
3	23.35	123.75	53.05	74.05	72.55	45.50	75.45	73.25	18.95	24.35	118.85	49.05	79.00	69.00	16.50	109.85	34.00	48.65
4	19.00	120.55	48.95	69.80	79.80	40.80	79.05	68.05	40.45	28.75	116.70	42.65	68.85	80.45	12.35	114.25	32.75	51.25
5	17.85	126.05	53.05	71.35	75.45	38.95	68.65	76.50	18.40	27.00	121.80	47.80	60.55	86.75	18.50	118.95	31.05	59.00
6	24.50	116.50	49.65	80.65	68.85	42.70	69.85	77.05	23.65	17.85	120.85	43.95	64.75	83.40	20.45	120.65	27.45	63.20
7	29.95	120.05	41.85	83.25	64.55	43.50	70.75	78.45	27.50	18.05	130.65	51.05	75.00	74.05	8.50	118.45	28.95	56.45
8	28.00	121.95	48.45	74.05	71.35	29.65	73.25	75.35	13.20	13.75	136.05	64.65	73.45	74.50	31.25	119.05	24.65	60.95
9	24.55	120.35	49.05	71.00	77.80	32.80	77.10	73.05	26.00	10.05	137.50	60.55	71.05	76.52	28.65	123.75	25.65	58.75
10	18.05	121.00	47.40	79.45	65.45	37.65	78.15	72.75	29.85	25.45	123.50	56.85	79.00	70.65	35.85	125.45	23.05	61.00
11	16.85	130.25	58.00	73.75	69.05	32.85	81.05	67.85	32.75	29.75	120.75	46.75	76.50	72.50	34.25	119.75	27.00	58.65
12	19.70	127.05	48.50	77.25	68.95	48.05	75.00	72.70	38.90	30.10	117.95	51.05	73.45	74.65	27.65	128.65	20.75	62.05
13	12.00	125.05	53.45	80.49	64.90	43.85	71.05	77.35	33.05	33.05	110.80	37.15	78.05	69.05	30.75	112.30	36.05	48.65
14	23.50	121.85	49.05	81.25	62.35	18.95	73.25	75.85	26.65	26.95	112.45	40.95	80.90	67.45	34.85	123.75	25.50	64.65
15	29.05	118.75	50.00	78.85	70.20	30.00	74.55	75.90	28.45	20.10	128.95	58.65	81.35	65.00	30.05	100.55	38.85	58.00

Table 10: *Distance from the two light sources and the initial position of Turtle X at each different light combination*

Replicates	Distances covered by Turtle X /cm ±0.05																	
	Light combinations /1st light source-2nd light source																	
	White/no light			White/white			White/red			White/yellow			White/green			White/blue		
	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position	From light source 1	From light source 2	From its initial position
1	18.95	112.00	34.50	80.65	68.55	19.50	72.60	76.50	12.75	20.90	123.45	52.55	70.65	78.95	119.05	120.05	25.65	59.05
2	24.55	124.45	48.90	65.50	75.00	43.75	75.85	71.45	34.70	24.35	120.65	58.90	75.45	72.35	17.85	124.45	20.95	64.65
3	28.55	120.85	46.75	78.55	70.95	48.00	74.05	75.50	36.50	28.95	109.75	45.45	73.00	76.05	14.55	120.65	26.55	64.45
4	27.05	121.05	51.55	76.00	72.35	51.90	67.80	79.75	34.00	9.00	130.90	52.55	67.80	78.75	24.50	127.85	20.90	61.25
5	23.25	119.85	49.05	74.35	74.60	57.85	80.90	67.55	27.85	13.25	136.65	58.90	69.05	76.55	28.85	109.85	37.85	59.00
6	19.75	125.55	47.65	79.05	68.75	53.45	71.00	75.05	24.65	17.75	131.35	59.65	71.25	76.35	32.65	104.55	40.05	57.55
7	16.85	130.75	58.00	70.05	76.05	47.65	77.35	72.35	20.99	31.65	115.85	48.45	75.25	73.45	38.25	100.75	47.80	54.35
8	10.00	125.75	47.85	68.90	78.65	56.00	78.05	70.45	18.95	28.65	112.75	38.90	78.90	70.00	39.00	112.75	36.55	59.05
9	13.75	121.25	48.00	69.75	78.35	38.75	72.35	77.00	43.25	18.90	119.45	40.75	80.95	65.75	41.65	120.45	28.65	56.85
10	24.75	121.85	49.45	80.95	67.85	37.05	79.05	70.35	48.15	10.45	130.90	62.35	78.55	67.80	26.75	125.65	24.90	68.90
11	28.65	120.90	51.25	81.70	65.45	35.25	67.85	78.25	30.05	6.75	140.65	66.45	76.05	69.05	28.90	123.90	35.65	64.35
12	23.05	119.85	45.05	79.45	67.80	38.95	71.05	75.10	35.65	34.00	110.75	38.55	74.35	73.65	24.05	114.70	31.25	60.45
13	31.05	116.55	50.85	68.00	80.95	41.00	79.80	69.05	48.95	28.75	110.50	32.80	76.00	73.50	28.65	118.65	27.05	57.05
14	26.85	121.35	44.45	71.35	77.00	26.05	73.45	75.15	28.00	35.45	105.80	27.85	78.25	70.75	21.75	123.45	29.00	52.75
15	28.00	120.75	43.85	75.15	73.25	30.85	76.25	72.35	35.05	27.05	120.45	43.00	72.35	75.15	29.05	106.55	41.15	60.55

3.2 Processed Data

Using the raw data presented in Tables 1-10, the processing was performed, which is shown in detail in the following table.

Equation	*Sample Calculation*
In order to calculate the angle, the cosine rule is used: $\cos A = \frac{b^2 + c^2 - a^2}{2bc}$ **Side a**, is the distance between the turtle's final position and light source 2. **Side c**, is the distance between the turtle's final position and its initial position. **Side b**, is the fixed distance between the turtle's initial position and light source 2. In order to carry on with the calculation, side b must be measured in the setting. Side b = 80.80 cm By finding "cos A", the angle A in degrees can be inferred, using $A = \arccos\left(\frac{b^2 + c^2 - a^2}{2bc}\right)$ **Angle Ω** is always constant; since the triangle BΩX is right angled, angle Ω is calculated using the tangent (tan) trigonometric number. $\tan\Omega = \frac{\omega}{x} = \frac{30.00}{75.00} = \frac{2}{5}$ Therefore, $\Omega = \arctan(\frac{2}{5}) = 21.80^{\circ}$ **Angle A** is added to angle Ω in order to determine whether the movement of the turtle was towards the changing light source or away from it. In the case that: • $\text{angle A} + \text{angle } \Omega = 90.00^{\circ}$ (±5.00°) the direction of the turtle is neither towars the changing light source nor towards the constant white light source: the turtle is unaffected by the changing light • $\text{angle A} + \text{angle } \Omega > 95.00^{\circ}$ the direction of the turtle is away form the changing light source and towards the constant white light source: the turtle is repelled from the changing light • $\text{angle A} + \text{angle } \Omega < 85.00^{\circ}$ the direction of the turtle is towards the changing light source and away from the constant white light source: the turtle is attracted to the changing light	Turtle I, distance covered in the first replicate in white/no light combination (*Table 1*). $\cos A = \frac{b^2 + c^2 - a^2}{2bc} = \frac{80.80^2 + 55.00^2 - 119.00^2}{2 \cdot (80.80) \cdot (55.00)} = \frac{-4607.36}{8888} = -0.5184$ $A = \arccos(-0.5184) = 121.22^{\circ}$ **Angle A + angle Ω** = $121.22^{\circ} + 21.80^{\circ} = 143.02^{\circ} > 90.00^{\circ}$ Thus, the turtle was repelled by *"no light"* (light source 2), directing its movement towards *"white"* (light s The same series of calculations is followed for the complete set of replicates, at each combination of lights turtle individuals. The angle results are presented in *Tables 11-15.*
$\text{mean angle} = \frac{\text{angle 1} + \text{angle 2} + \cdots + \text{angle 15}}{15}$	Turtle I, mean angle in fifteen replicates in white/no light combination (Table 11). $\text{mean angle Turtle I} = \frac{\text{angle 1} + \text{angle 2} + \cdots + \text{angle 15}}{15} = 144.50^{\circ}$
$\text{mean angle all Turtles} = \frac{\text{mean angle Turtle I} + \text{mean angle Turtle II} + \cdots + \text{mean angle Turtle X}}{10}$	Turtle I-X, mean angle in white/no light combination (Table 16). $\text{mean angle all Turtles} = \frac{\text{mean angle Turtle I} + \text{mean angle Turtle II} + \cdots + \text{mean angle Turtle X}}{10}$

n e r	$\sqrt{\frac{\Sigma(X - \bar{X})^2}{(n - 1)}}$ where: X = each score $\bar{X}$ = the mean or average n = the number of values Σ means we sum across the values *Figure 2: Standard Deviation mathematical formula*[2]	Turtles I-X, mean angle in white/no light combination and standard deviation from the mea 16).

Table 11: *Sum of angle A and angle Ω and direction of movement of Turtles I & II, Repulsion from 2nd light source I (R), Attraction to 2nd light source (A) Unaffected (U)*

Replicates	***Angle and Direction of movement of Turtle I & II / degrees ±0.01***											
	Light combinations /1st light source-2nd light source											
	White/no light		***White/white***		***White/red***		***White/yellow***		***White/green***		***White/blue***	
	Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		*Angle A + Angle Ω*		*Angle A + Angle Ω*	
1	143.02	135.72	107.39	91.37	119.66	77.27	133.21	141.91	81.22	52.77	40.27	58.99
2	142.28	134.83	103.81	78.10	97.22	76.24	154.72	183.64	80.51	73.92	48.95	28.90
3	146.76	141.07	97.10	79.55	99.15	94.20	184.93	184.49	94.50	86.15	32.62	25.13
4	155.41	106.76	109.72	93.82	83.34	63.18	184.07	187.02	87.14	78.39	71.77	44.08
5	105.39	88.49	105.54	107.26	105.85	98.68	153.96	189.88	105.33	50.95	27.12	61.92
6	109.80	91.14	92.83	101.36	98.48	112.54	173.68	181.07	96.32	90.32	36.30	65.72
7	146.60	169.74	97.37	79.82	80.14	100.16	162.05	179.37	94.73	84.89	26.07	28.98
8	120.93	180.24	96.95	97.04	80.91	91.20	156.25	184.99	90.44	119.77	33.20	37.11
9	131.76	99.78	100.03	78.97	98.13	117.31	170.93	197.44	90.60	127.81	28.98	50.58
10	157.11	150.56	106.25	72.04	102.31	109.47	167.58	169.71	90.26	80.44	28.92	36.81
11	159.71	126.15	157.65	91.74	107.58	160.87	195.55	165.03	87.30	71.11	27.99	55.68
12	170.55	95.94	150.35	82.31	103.40	161.09	182.89	161.15	56.65	85.52	29.01	39.64
13	157.53	105.73	98.79	42.23	88.22	104.13	189.82	164.06	98.89	105.01	25.42	45.26
14	156.23	97.15	100.66	49.38	57.13	97.84	168.01	124.98	92.88	101.63	28.84	24.04
15	164.41	89.92	93.78	60.87	58.37	83.44	194.44	125.32	103.13	71.45	22.84	26.65
Mean	***144.50 R***	***120.88 R***	***107.88 R***	***80.39 A***	***91.99 U***	***103.17 R***	***171.47 R***	***169.34 R***	***89.99 U***	***85.34 U***	***33.89 A***	***41.97 A***
SD	***19.57***	***29.99***	***19.41***	***18.42***	***17.51***	***27.62***	***17.56***	***22.70***	***11.57***	***21.56***	***12.38***	***14.05***

[2] http://www.drtomoconnor.com/images/diagrams/standarddeviation.gif

Table 12: *Sum of angle A and angle Ω and direction of movement of Turtle III & IV Repulsion from 2nd light source I (R), Attraction to 2nd light source (A) Unaffected (U)*

Replicates	***Angle and Direction of movement of Turtle III & IV / degrees ±0.01***											
	Light combinations /1st light source-2nd light source											
	White/no light		***White/white***		***White/red***		***White/yellow***		***White/green***		***White/blue***	
	Sum of Angle A & Angle Ω		Sum of Angle A & Angle Ω		Sum of Angle A & Angle Ω		Sum of Angle A & Angle Ω		Sum of Angle A & Angle Ω		Sum of Angle A & Angle Ω	
1	126.20	130.64	101.04	103.71	148.13	71.81	166.27	164.41	69.21	84.99	43.71	33.05
2	110.83	149.09	105.03	94.16	151.35	78.79	187.59	167.54	57.62	101.12	24.93	33.48
3	110.22	153.51	100.01	79.34	166.23	87.74	133.35	164.56	89.20	110.88	46.77	45.05
4	140.96	111.75	124.68	146.06	195.61	49.92	167.22	189.64	120.92	64.50	32.89	67.08
5	132.51	91.23	99.89	89.11	155.34	91.64	151.95	163.09	95.27	81.13	34.65	59.63
6	129.72	84.13	79.87	165.68	164.17	95.16	172.71	175.97	101.35	109.10	31.01	31.89
7	179.23	135.40	92.38	91.81	174.92	98.57	169.52	177.88	96.61	91.01	30.53	33.48
8	147.88	151.29	83.30	62.36	155.16	116.94	157.06	165.62	85.32	95.21	25.12	28.21
9	77.79	121.10	70.61	117.94	175.48	98.28	160.13	179.94	98.97	81.37	35.69	32.44
10	134.84	137.17	62.34	106.58	173.75	132.25	161.80	184.26	79.61	92.35	25.51	31.04
11	160.37	173.62	83.30	106.57	155.78	98.92	167.64	158.80	94.38	84.23	43.16	38.73
12	153.79	127.00	95.22	95.13	174.56	110.93	144.93	152.24	96.54	95.56	31.82	33.23
13	179.24	140.05	82.48	111.17	157.26	111.51	163.00	175.86	104.39	64.59	36.00	56.67
14	169.68	124.77	95.93	149.67	185.29	108.48	164.74	181.20	112.57	56.61	44.38	28.99
15	144.47	179.36	93.00	48.44	160.09	96.60	179.70	170.25	112.70	73.81	42.67	45.27
Mean	***139.85 R***	***134.01 R***	***91.27 U***	***104.52 R***	***166.21 R***	***96.50 R***	***163.17 R***	***171.42 R***	***94.31 U***	***85.76 U***	***35.26 A***	***39.88 A***
SD	***27.56***	***26.33***	***15.10***	***31.50***	***13.46***	***19.79***	***13.22***	***10.32***	***16.61***	***16.04***	***7.41***	***12.23***

Table 13: *Sum of angle A and angle Ω and direction of movement of Turtle V & VI Repulsion from 2nd light source I (R), Attraction to 2nd light source (A) Unaffected (U)*

Replicates	***Angle and Direction of movement of <u>Turtle V & VI</u> / degrees ±0.01***											
	Light combinations /1st light source-2nd light source											
	White/no light		***White/white***		***White/red***		***White/yellow***		***White/green***		***White/blue***	
	Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω	
1	158.36	195.30	87.29	60.26	89.82	80.25	156.14	173.81	86.90	99.06	30.90	35.23
2	145.09	194.93	89.97	78.37	90.62	103.40	133.74	159.83	107.19	100.13	28.19	30.82
3	187.19	156.44	82.32	64.56	86.09	99.66	172.85	192.93	112.88	96.67	28.84	31.67
4	109.07	146.17	110.34	179.64	100.50	56.55	160.23	181.69	67.08	101.66	52.74	189.27
5	104.31	97.21	97.72	81.36	102.29	50.91	175.95	139.12	72.44	123.33	26.10	31.71
6	101.61	134.98	103.88	97.74	94.61	80.03	153.64	163.16	97.58	83.52	39.84	27.45
7	108.01	136.94	99.34	86.65	91.58	96.26	148.76	179.18	86.06	95.13	40.21	24.76
8	158.07	166.90	105.90	91.36	101.19	89.74	183.48	161.13	89.42	64.23	27.89	23.67
9	114.63	129.97	89.40	89.73	100.32	121.09	170.12	169.55	80.31	86.57	30.42	24.85
10	148.43	186.51	85.15	99.20	84.69	99.94	151.17	176.87	97.24	78.87	29.47	37.71
11	126.70	157.08	83.84	76.49	119.89	98.21	173.54	174.40	99.91	101.35	33.65	29.60
12	96.60	115.78	64.53	98.06	102.83	99.58	178.41	166.05	97.37	76.56	31.21	29.97
13	114.86	143.07	70.00	56.62	104.67	122.10	170.32	155.47	59.63	96.96	29.45	29.80
14	93.46	106.38	90.01	102.57	87.17	79.60	142.35	155.01	79.80	100.35	24.00	49.03
15	109.50	123.58	73.26	57.34	92.90	82.01	159.02	179.41	73.72	76.61	28.22	45.14
Mean	***125.06 R***	***146.08 R***	***88.86 U***	***88.00 U***	***96.61 R***	***90.62 U***	***161.98 R***	***168.51 R***	***87.17 U***	***92.07 U***	***32.08 A***	***42.71 A***
SD	***27.77***	***30.44***	***13.21***	***29.83***	***9.24***	***19.96***	***14.41***	***13.41***	***15.13***	***14.45***	***7.24***	***41.17***

Table 14: *Sum of angle A and angle Ω and direction of movement of Turtle VII & VIII, Repulsion from 2nd light source I (R), Attraction to 2nd light source (A) Unaffected (U)*

Replicates	***Angle and Direction of movement of Turtle VII & VIII / degrees ±0.01***											
	Light combinations /1st light source-2nd light source											
	White/no light		***White/white***		***White/red***		***White/yellow***		***White/green***		***White/blue***	
	Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω	
1	167.14	191.90	52.43	88.79	79.32	65.11	172.14	190.27	108.16	98.34	32.91	51.30
2	167.35	146.06	93.51	98.72	96.05	46.60	176.03	155.02	96.22	83.65	30.29	45.53
3	171.23	179.85	97.97	105.62	91.58	36.29	193.17	165.20	95.96	94.50	31.16	32.78
4	147.74	182.81	77.84	89.86	83.69	80.12	159.56	139.86	89.44	93.65	32.30	37.28
5	168.35	193.81	79.34	87.86	87.45	84.90	174.74	174.25	94.90	91.14	27.29	35.49
6	165.32	161.62	88.84	95.60	86.71	79.21	185.11	152.25	90.72	95.50	35.92	51.67
7	180.12	177.64	95.95	86.68	97.50	98.19	177.12	170.93	96.99	93.11	40.15	54.69
8	159.18	156.24	100.25	93.29	85.72	88.45	174.04	136.84	100.08	103.37	32.42	44.11
9	172.09	169.88	91.26	100.88	88.14	94.93	177.35	152.73	111.00	96.61	35.08	46.69
10	168.83	186.35	78.79	90.77	81.52	84.88	184.28	166.41	103.42	87.00	31.23	35.25
11	142.14	162.10	91.57	79.69	86.78	75.41	178.37	143.98	92.39	82.70	31.45	32.37
12	152.89	146.64	60.96	80.31	80.17	104.29	178.73	174.82	86.98	92.22	29.57	34.38
13	158.88	132.36	68.61	90.01	81.76	97.76	157.45	193.29	88.78	106.35	30.56	26.52
14	172.52	178.63	82.46	86.34	102.77	74.53	173.66	154.15	89.49	109.28	37.65	31.29
15	185.34	171.12	97.27	84.66	95.66	75.48	163.99	167.79	93.09	108.05	27.95	50.63
Mean	***165.27 R***	***169.13 R***	***83.80 A***	***90.61 U***	***88.32 U***	***79.08 A***	***175.05 R***	***162.52 R***	***95.84 R***	***95.70 R***	***32.40 A***	***40.66 A***
SD	***11.53***	***18.04***	***14.28***	***7.24***	***7.01***	***18.68***	***9.39***	***16.84***	***7.14***	***8.25***	***3.52***	***8.98***

Table 15: *Sum of angle A and angle Ω and direction of movement of Turtle IX & X, Repulsion from 2nd light source I (R), Attraction to 2nd light source (A) Unaffected (U)*

Replicates	***Angle and Direction of movement of Turtle IX & X / degrees ±0.01***											
	Light combinations /1st light source-2nd light source											
	White/no light		***White/white***		***White/red***		***White/yellow***		***White/green***		***White/blue***	
	Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω		Angle A + Angle Ω	
1	152.15	171.74	74.64	88.31	78.15	87.77	156.51	156.28	90.86	63.03	46.99	33.10
2	187.44	168.02	83.79	82.48	66.09	83.86	170.72	140.42	79.18	77.81	29.24	32.39
3	155.95	163.03	84.82	83.41	81.99	90.31	152.71	139.82	61.89	87.79	31.92	38.47
4	156.94	152.82	95.73	84.35	79.07	97.85	161.69	179.28	105.79	98.25	34.40	27.82
5	161.58	155.03	89.85	79.16	91.84	74.28	163.02	177.51	124.45	93.02	40.23	47.70
6	146.59	176.53	80.24	88.74	94.27	89.62	171.70	159.82	111.95	92.25	38.75	49.47
7	176.85	162.02	74.56	89.19	97.06	81.04	185.92	147.29	57.36	86.96	35.11	56.76
8	161.78	176.57	82.88	94.22	83.07	72.86	160.11	159.79	89.02	81.82	33.75	46.35
9	156.24	160.97	94.78	78.38	85.40	91.10	174.71	179.19	92.97	75.97	32.71	35.12
10	161.77	159.11	74.79	74.05	85.63	81.74	148.51	153.62	82.64	74.04	31.44	38.66
11	160.79	153.06	79.46	78.57	77.30	96.17	162.74	167.19	85.58	78.03	34.68	47.14
12	179.68	164.69	80.07	97.32	85.79	89.78	147.19	154.83	89.15	86.14	29.00	41.34
13	158.17	144.75	75.05	94.12	93.94	80.10	158.48	172.14	78.80	86.93	36.75	32.74
14	160.04	171.81	33.36	86.70	91.62	90.21	153.93	171.59	77.25	77.19	37.49	28.26
15	150.69	171.68	80.75	***84.42***	91.74	85.35	156.44	173.71	70.47	92.21	48.36	51.47
Mean	***161.78 R***	***163.45 R***	***78.99 A***	***88.31 A***	***85.53 U***	***86.14 U***	***161.63 R***	***162.16 R***	***86.49 U***	***83.43 A***	***36.06 A***	***40.45 A***
SD	***11.20***	***9.41***	***14.34***	***8.12***	***8.26***	***7.22***	***10.46***	***13.45***	***17.85***	***9.18***	***5.70***	***8.96***

Chapter IV: DISCUSSION

4.1 Evaluation of Results

The results of the processing revealed that turtles indeed demonstrated a different behaviour concerning their mode of movement, in response to changes in the combinations of lights (*Table 16* and *Figures II & III*). As such, an overall tendency to be directed towards the blue light was observed as already described in previous studies (Environmental Assessment Guideline No. 5, Protecting Marine Turtles from Light Impacts, 2010, and Gless et al, 2008), with a mean angle sum of 37.54° and very small SD (4.04°). However, the expected attraction towards green light was not confirmed, since the results demonstrated that individual turtles were mostly unaffected by it, remaining in about the middle area of the experimental setup (mean angle sum of 89.61° and again small SD, 4.61°). Comparable to these results were the movement patterns of the turtles when both sources were white light. The mean angle sum was 89.87° however, with larger SD value (9.55°), suggesting that the turtles were undecided as to whether to move towards the one light source or the other, which is expected.

The turtles were repelled by the yellow light (mean angle sum was 166.73°, with small SD value (4.98°), again in agreement with previous studies (Wang et al, 2007). A type of repulsion for the turtles was also demonstrated in the case of white light/no light combination, in which turtles actually referred to move towards the light source, avoiding the darker side (mean angle sum was 147.00°, with quite large SD value 17.33°). The large SD value probably suggests that turtles wandered around during their movement, reaching at different final positions each time. Red light also repelled the turtles but to a much lower degree than yellow or darkness. The mean angle sum was 98.42°, but the largest SD value measured (24.77°), clearly illustrates the fact that turtles were behaving inconsistently in response to red light. This is why some of them were unaffected, while others were repelled. There was even one individual that was actually attracted to it. These findings agree with previous studies, which suggest that in order for red light to attract the young individual turtles it must be 100 –

600 times stronger than blue light (Fehring, 1972, and Granda & O'Shea, 1972). It would have been interesting to test this prediction by changing the intensity of the light lamps, but would have required a number of more sophisticated equipment than the ones available to the author.

Table 16: *Mean sum of Angles A and Ω and direction of movement of all Turtles at different combinations of light, Repulsion from 2nd light source I (R), Attraction to 2nd light source (A) Unaffected (U)*

Turtles	***Mean Angle and Direction of movement of all Turtles /degrees ±0.01***											
	Light combinations /1st light source-2nd light source											
	White/no light		***White/white***		***White/red***		***White/yellow***		***White/green***		***White/blue***	
	Angle A + Angle Ω	Direction	Angle A + Angle Ω	Direction	Angle A + Angle Ω	Direction	Angle A + Angle Ω	Direction	Angle A + Angle Ω	Direction	Angle A + Angle Ω	Direction
I	144.50	R	107.88	R	91.99	U	171.47	R	89.99	U	33.89	A
II	120.88	R	80.39	A	103.17	R	169.34	R	85.34	U	41.97	A
III	139.85	R	91.27	U	166.21	R	163.17	R	94.31	U	35.26	A
IV	134.01	R	104.52	R	96.50	R	171.42	R	85.76	U	39.88	A
V	125.06	R	88.86	U	96.61	R	161.98	R	87.17	U	32.08	A
VI	146.08	R	88.00	U	90.62	U	168.51	R	92.07	U	42.71	A
VII	165.27	R	83.80	A	88.32	U	175.05	R	95.84	R	32.40	A
VIII	169.13	R	90.61	U	79.08	A	162.52	R	95.70	R	40.66	A
IX	161.78	R	78.99	A	85.53	U	161.63	R	86.49	U	36.06	A
X	163.45	R	84.42	A	86.14	U	162.16	R	83.43	A	40.45	A
Mean	***147.00***	***R***	***89.87***	***U***	***98.42***	***R***	***166.73***	***R***	***89.61***	***U***	***37.54***	***A***
SD	***17.33***		***9.55***		***24.77***		***4.98***		***4.61***		***4.04***	

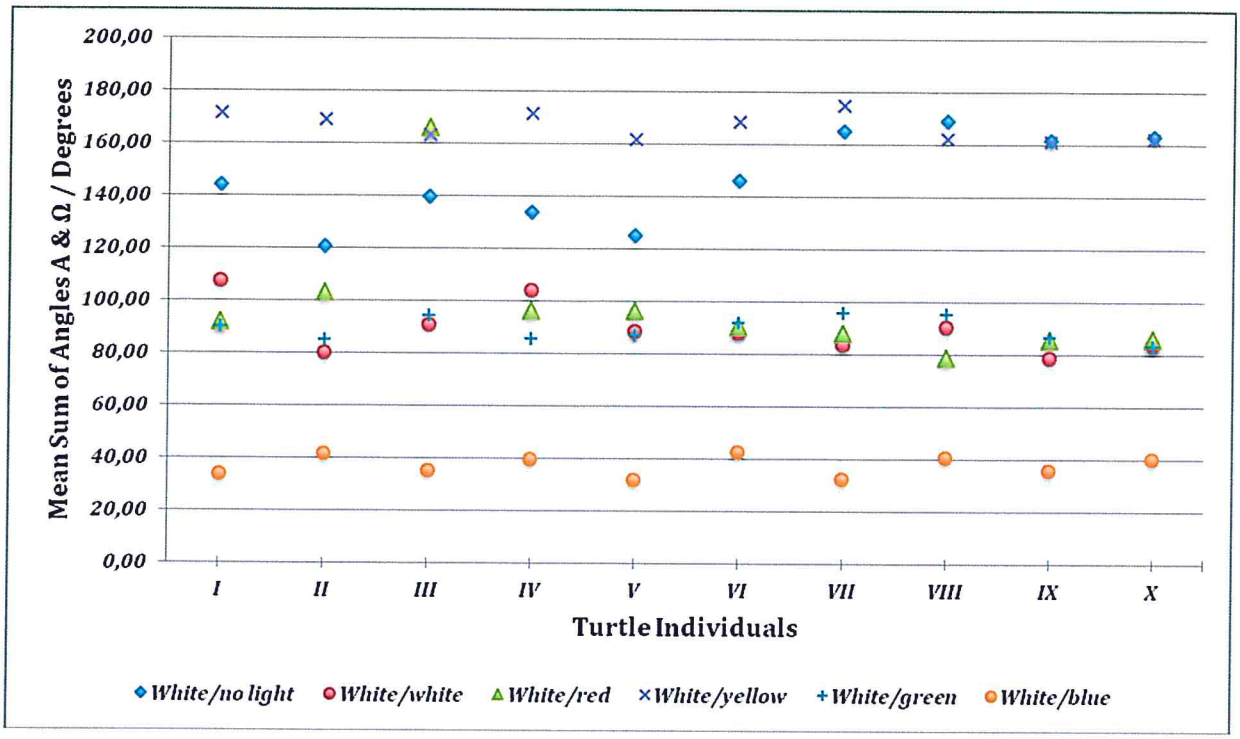

Figure II: Mean Sum of Angles A and Ω, denoting the direction of movement of 10 individual turtles versus different light combinations

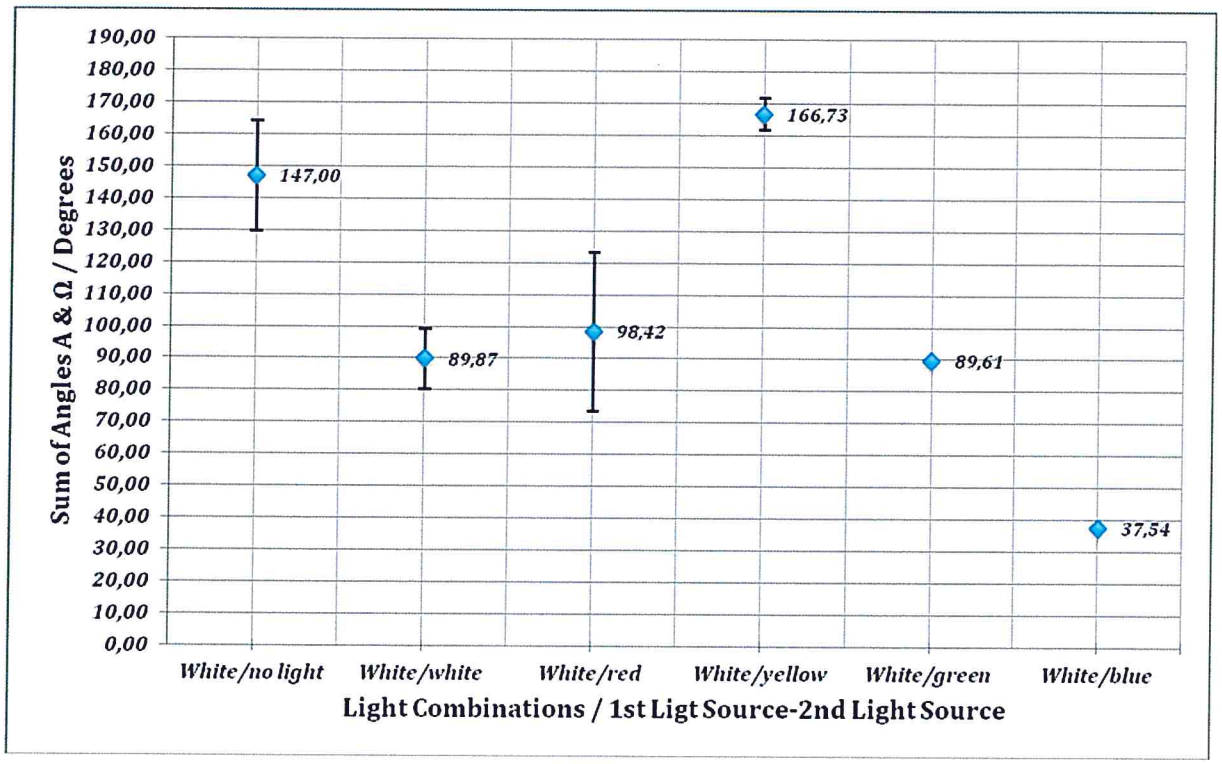

Figure III: Mean Sum of Angles A and Ω of all turtle individuals, denoting the direction of movement versus different light combinations (Error bars = ±1 SD)

In terms of the statistical analysis that was performed, the following values were calculated.

Table 17: *Descriptive Statistics*

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
VAR 1: White light/No light	10	48,25	120,88	169,13	147,0010	17,33063	300,351	-0,169
VAR 2: White light/White light	10	28,89	78,99	107,88	89,8740	9,54986	91,200	1,028
VAR 3: White light/Red light	10	87,13	79,08	166,21	98,4170	24,76599	613,354	2,731
VAR 4: White light/Yellow light	10	13,42	161,63	175,05	166,7250	4,98354	24,836	0,401
VAR 5: White light/Green light	10	12,41	83,43	95,84	89,6100	4,60824	21,236	0,242
VAR 6: White light/Blue light	10	10,09	32,08	42,17	37,4820	3,96721	15,739	-0,186
Valid N (listwise)	10							

Table 18: *Descriptive Statistics*

	Skewness	Kurtosis	
	Std. Error	Statistic	Std. Error
VAR 1: White light/No light	0,687	-1,435	1,334
VAR 2: White light/White light	0,687	0,266	1,334
VAR 3: White light/Red light	0,687	8,035	1,334
VAR 4: White light/Yellow light	0,687	-1,530	1,334
VAR 5: White light/Green light	0,687	-1,654	1,334
VAR 6: White light/Blue light	0,687	-1,859	1,334
Valid N (listwise)			

The paired samples t-test was performed to see if the differences measured between the angles of movement followed by the turtles were significant or not (p 0.05). The results are shown in the following tables.

Table 19: *Paired Samples Test*

Variable Pairs		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	
					Lower	Upper
Pair 1	VAR 1 - VAR 2	57,12700	21,50349	6,80000	41,74433	72,50967
Pair 2	VAR 1 - VAR 3	48,58400	35,39485	11,19284	23,26405	73,90395
Pair 3	VAR 1 - VAR 4	-19,72400	18,66649	5,90286	-33,07720	-6,37080
Pair 4	VAR 1 - VAR 5	57,39100	16,11115	5,09479	45,86577	68,91623
Pair 5	VAR 1 - VAR 6	109,51900	17,80398	5,63011	96,78280	122,25520
Pair 6	VAR 2 - VAR 3	-8,54300	25,79394	8,15676	-26,99487	9,90887
Pair 7	VAR 2 - VAR 4	-76,85100	9,06232	2,86576	-83,33379	-70,36821
Pair 8	VAR 2 - VAR 5	0,26400	10,28784	3,25330	-7,09548	7,62348
Pair 9	VAR 2 - VAR 6	52,39200	10,82443	3,42299	44,64867	60,13533
Pair 10	VAR 3 - VAR 4	-68,30800	25,93287	8,20069	-86,85926	-49,75674
Pair 11	VAR 3 - VAR 5	8,80700	24,18331	7,64743	-8,49269	26,10669
Pair 12	VAR 3 - VAR 6	60,93500	25,80602	8,16058	42,47448	79,39552
Pair 13	VAR 4 - VAR 5	77,11500	6,05780	1,91564	72,78151	81,44849
Pair 14	VAR 4 - VAR 6	129,24300	6,61160	2,09077	124,51335	133,97265
Pair 15	VAR 5 - VAR 6	52,12800	6,80015	2,15040	47,26346	56,99254

Table 20: Paired Samples Test

Variable Pairs		t	df	Sig. (2-tailed)
Pair 1	*VAR00001 - VAR00002*	8,401	9	0,000
Pair 2	*VAR00001 - VAR00003*	4,341	9	0,002
Pair 3	*VAR00001 - VAR00004*	-3,341	9	0,009
Pair 4	*VAR00001 - VAR00005*	11,265	9	0,000
Pair 5	*VAR00001 - VAR00006*	19,452	9	0,000
Pair 6	*VAR00002 - VAR00003*	-1,047	9	0,322
Pair 7	*VAR00002 - VAR00004*	-26,817	9	0,000
Pair 8	*VAR00002 - VAR00005*	0,081	9	0,937
Pair 9	*VAR00002 - VAR00006*	15,306	9	0,000
Pair 10	*VAR00003 - VAR00004*	-8,330	9	0,000
Pair 11	*VAR00003 - VAR00005*	1,152	9	0,279
Pair 12	*VAR00003 - VAR00006*	7,467	9	0,000
Pair 13	*VAR00004 - VAR00005*	40,255	9	0,000
Pair 14	*VAR00004 - VAR00006*	61,816	9	0,000
Pair 15	*VAR00005 - VAR00006*	24,241	9	0,000

In order to draw conclusions about any statistically significant differences, the t calculated must be higher than the t critical, for 9 d.f. (p 0.05). Observing the pairs of variables we can see that in the case of white light/no light and white light/white light, the t calculated is larger than the t critical, thus the difference is significant. The same is true for combinations the following combinations of light: white/no and white/red, white/no and white/green, white/no and white/blue. The only combination in which the difference between the results is statistically non-significant was the white/no and white/yellow, suggesting that the effect of darkness in repelling the turtles is not significantly different than the repelling effect of yellow light. Then the combinations of white/white and white/red, as well as white/white and white/yellow, and white/white and white/green were again found to be statistically non-significant according to the t test. This delineates the fact that the animals were not specially choosing their direction of movement when both sources of light were white, in comparison to red light (again unaffected), yellow light (repelled) and green light (unaffected).

However, there was significance in the difference between the combination white/white and white/green. When the combination white/red and white/yellow was compared, the t test showed insignificant difference, again suggesting that the effect of yellow and red is overall repelling for the animals, but without being statistically different. The white/red and white/green as well as the white/red and white /blue combinations showed significant differences, suggesting that attraction from blue is of importance for the turtles. Then the combination white/yellow and white/green as well as white/yellow and white/blue showed significant difference, suggesting the opposing effect of the different wavelengths. Finally, the combination white/green and white/blue showed significant difference as well, demonstrating that the attractive effect of blue is strong for the turtles against the indifferent behaviour they show against green light.

4.2 Evaluation of Procedure

The experimental investigation unavoidably obtained a number of important limitations. The following table includes limitations and realistic modifications concerning the experimental procedure.

Limitation	***Modification***
Firstly, the turtle individuals were not actually hatchlings. Therefore, they have developed a certain degree of adaptation in the lights surrounding them.	It would have been nearer to real conditions if hatchlings could have been investigated.
Secondly, the turtles were neither all from the same batch,. These two parameters may have affected the behaviour of the animals against the different combinations of light and may account for large deviations observed in some of the trials.	Thus, the individuals should have been more closely related both in their genetic makeup (siblings).
A third limitation was the human presence. The turtles were used to the presence of humans around them and may have not been affected by it.	However, it would have been closer to reality if the turtles could have been observed without being continuously disturbed.
Another limitation concerning the setting of the experiment was the dimensions as well as the terrain. Firstly, the rectangle constructed was small, not allowing to the animals to move freely. Secondly, the surface on which the animals were moving was far from their natural one, which might have added up to the stress they were feeling, affecting thus their realized route.	The ideal setting would have been the natural one, such as the seashore or a more elaborately structured artificial setting, much closer to reality.
Another important limitation pertains to the ethical considerations of experimentation with animals and the fact that it is inevitable to perform the investigation without affecting the turtles in any way.	It must be stated, that the animals were neither deliberately, nor accidentally harmed in any way, whatsoever.
Additionally, concerning the light sources, it should have been more appropriate to use light lamps with minimum diffusion, such as beam lamps or fluorescent sticks, that minimize scattering and diffusion of light, making the measurements much more accurate.	As can be seen in the photographs in *Appendix I*, the diffusion of light was important and that limited the reliability of the measurements. However, one must not forget that real conditions in natural settings include a great degree of light scattering and diffusion, which add more perplexity to turtles' perception and final route decisions.
Finally, although it seems that the light pollution affected the animals' selections of the route, it would have been more appropriate to examine more species of aquatic turtle or even other reptiles or amphibian species and collect measurements to construct a more holistic understanding of the phenomenon.	Although interesting, such an investigation would have required more elaborate equipment, such as cameras or tagging tools and protocols, in order to mimic the real conditions and collect reliable measurements.

4.3 Conclusion

The investigation was successful in confirming previously published research conclusions relative to the effect of the different wavelength of light on the route chosen by the young individual turtles. It seems that blue has an attractive role, perhaps due its resemblance to the oceanic hues, and is instinctively followed by the youngsters, upon hatching, in order to increase their survival rate, by rapidly finding the sea. On the other hand, it was demonstrated that yellow and red light wavelengths actually repel the turtles, as does the absence of light, highlighting the disruptive effect that city lights may have on the routinely followed routes of turtles. The resulting disorientation may greatly decrease the survival rate of the animals. Green light was not shown to affect the animals.

It has been shown previously that except turtles, other animals, like frogs are adversely affected by light pollution, and have decreased in population, due to urban sprawling (decrease in the mating chorus from male frogs, diminishes intercourse events). Specific frog species and salamanders make use of a light-dependent type of compass in order to orient themselves and guide their migratory behavior to the selected breeding sites. Introduced light has been shown to cause developmental abnormalities, like decreased sperm production, retinal damage and genetic mutations (Scheling, L. 2006; Barrett, K., and Guyer, C. 2008; and Woltz, et al 2008). Furthermore, migrating birds get greatly disoriented, failing to reach their destination and many times being killed in the process (Malakoff 2001).

Conclusively, it is evident that light pollution is of great importance for the survival of wildlife species including turtles and should be taken under consideration, when civil structures building is about to take place along the shoreline. The conduction of further research to exactly highlight the relevance of light pollution to behavioural patterns of various animal species is therefore, of prime significance in modern society. Especially, within the Greek territory where many endemic species thrive and the marine biota are greatly diverse, such research is not only needed, but it must become a critical priority, in order to protect their habitats and to avoid accidental by-catch in fishery lines. Therefore, special consideration must be given to conservation strategies and legislation.

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APPENDIX I

Photographs taken during the course of the experimental investigation

Figure IV: Two of the turtles in their aquarium

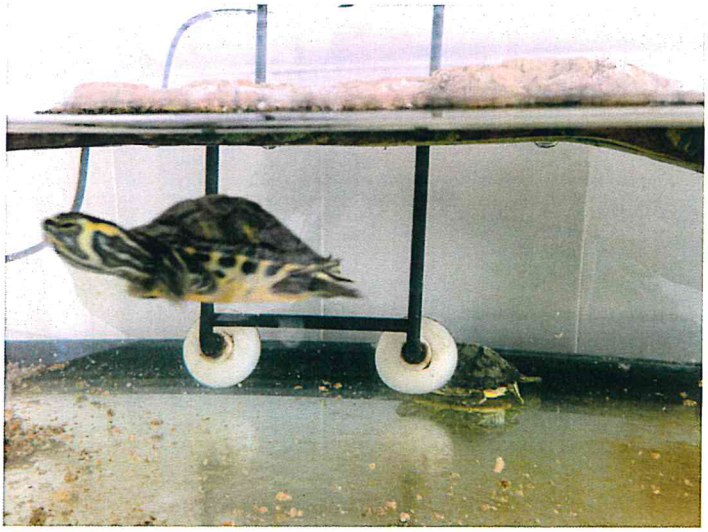

Figure V: The turtles underwater

Figure VI: Close-up view of the turtles

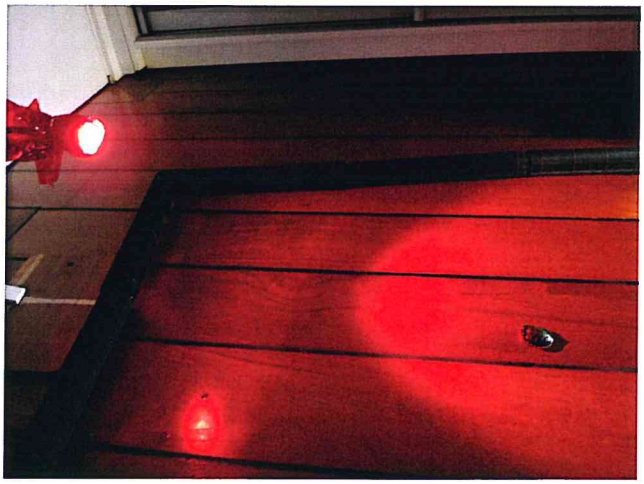

Figure VII: One of the turtles during the preliminary trial of the experiment

Figure VIII: The scattering of light form the source is evident in the preliminary trial of the experiment

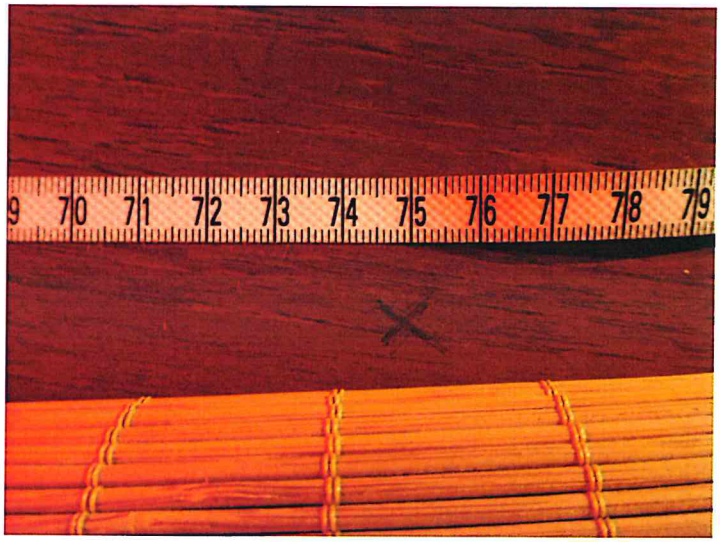

Figure IX: x denotes the starting point for each individual in the preliminary trial of the experiment

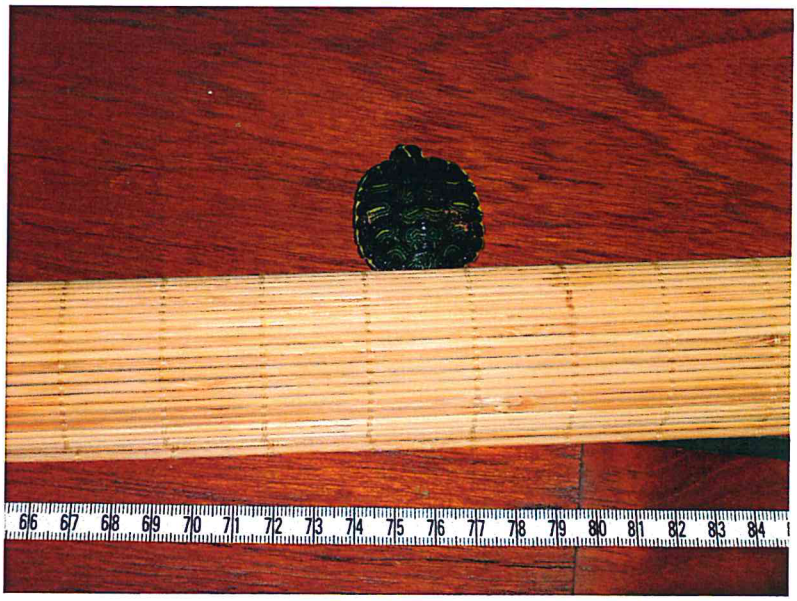

Figure X: Individual turtle at the starting point in the preliminary trial of the experiment